AAPET/ESST RELATED EFFICIENCY & EMISSIONS PROJECT SUMMARY

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INTRODUCTION

Improving automobile fuel efficiency continues to be an important national goal and a necessary step towards reducing our nation's dependence on foreign oil. Internal combustion engines have historically operated in a fuel rich mode in order assure easy start-up, smooth operation, and fast response to on-demand acceleration. New lean-burn engine concepts, now being developed, will require advanced control technologies and more durable materials due to higher operating temperatures. There are six Advanced Automotive Piston Engine Technology Programs at the Pacific Northwest National Laboratory that support these goals and the ESST Low Emission Partnership: (1) Powertrain Sensors & Actuators, (2) New Technologies for the Reduction of Automobile Exhaust Emissions, (3) Cylinder Design for Reduced Emissions Origins, (4) Superplastic Forming of Stainless Steel Automotive Components, (5) Fuel/Combustion System Optimization, and (6) Ultra-High Durability, High-Temperature Spark Delivery Subsystems.

Powertrain Sensors & Actuators

The objective of this project is to develop processes that will aid in the manufacture of planar, thin-film ceramic automotive sensors and solid state metal oxide sensors for emission monitoring. The main focus of this program is on developing ceramic processing techniques that are both reliable and suitable for high volume production.

Approach:

A primary goal of this project is to develop aqueous-based processing methods and thereby eliminate volatile organics which pose a waste disposal problem. Important objectives include the development of aqueous tape casting processes that can utilize commercially available binders and that are scalable to commercial production.

New Technologies for the Reduction of Automobile Exhaust Emissions

This project combines previous research on the development of selective, thermally stable materials for use as hydrocarbon traps with new research on the development of plasma assisted devices that will simultaneously oxidize hydrocarbons and reduce NO_x. The feasibility of plasma-based technologies, using catalytic materials, to mediate exhaust gas emissions are being investigated.

Approach:

The two primary avenues of research combine nonthermal plasma destruction methods with studies on oxide surface catalysis. Specific activities include the continued development of the packed bed corona discharge reactor, improvements in the pack bed design, and selection of bed materials. Demonstrations will be performed to show that plasma assisted systems reduce NO_x and oxidize hydrocarbons from a test exhaust stream. Parallel work is attempting to address the nature of the reaction mechanisms in catalysis reactions that will provide the information for the design of improved catalyst for packed bed corona reactors. Materials that are known to be active three-way and NO_x reduction catalysts at high temperatures are being investigated under nonthermal activation conditions. Specially tailored materials will be used to optimize the nonthermal catalytic destruction of exhaust components.

Cylinder Design for Reduced Emission Origins

One way to reduced regulated tailpipe emissions is to reduce engine-out hydrocarbon emissions by minimizing or eliminating their sources of generation. The primary purpose of this project was to bring the latest diagnostic technology to bear on the characterization of the chemical and physical processes that occur within an engine cylinder. An important objective was to characterize the molecular species of post combustion in-cylinder hydrocarbon reactions as well as to evaluate oil film-fuel reactions.

Conclusions:

This project was terminated in FY96. Time-resolved Laser-Raman Spectroscopy was successfully used to determine the rates of dissolution of several volatile hydrocarbons in oil films as a function of temperature and total pressure. As long as a liquid hydrocarbon was present, i.e., below the boiling point of the hydrocarbon, the dissolution kinetics were entropically driven and limited by mass transport of the vapor molecules at the vapor/oil film interface. When no liquid hydrocarbon was present, i.e., above the boiling point of the hydrocarbon, a solubility limit was observed. These studies demonstrated the potential of Laser Raman Spectroscopy for determining rate loss and thermodynamic constants related to the dissolution of vapor molecules in thin liquid films.

Superplastic Forming of Stainless Steel Automotive Components

Stringent future engine exhaust emissions standards are forcing auxiliary emission control strategies to be developed around the catalytic converter. During cold start, the converter is at insufficient temperature for catalytic reactions to occur resulting in higher levels of hydrocarbon and carbon monoxide emissions. The purpose of this program is to develop a process for making double or multiwall stainless manifolds, exhaust pipes, and unique converter designs that will reduce converter "light-off" time by reducing thermal energy loss.

Approach:

Superplastic Forming (SPF) has been chosen as a cost-effective method for making complex multiwall exhaust components. This forming process provides an economical alternative to conventional dual wall manifold fabrication methods, which are complex, expensive, and not easily automated. Innovative forming techniques are being developed to allow an insulated dual manifold section to be formed from welded flat sheet stock. The forming of sheet packs with insulating interlayers is being pursued as a potentially reliable method for fabricating insulated systems.

Fuel/Combustion System Optimization

In this project, holographic imaging techniques are being used to obtain three dimensional information on fuel droplet size, velocity, and evaporation rate within a combustion chamber. These measurements will be used to develop a better understanding of the relationships between mixture quality on either side of the intake valve. Improvements in combustion performance should lead to better fuel efficiency.

Approach:

Holographic imaging of droplets and particulates is being adapted to the characterization of fuel sprays. This is a three step process that starts with the recording of a hologram within the spray plume followed by reconstruction of the hologram and capturing of the digital image. The three dimensional images are then processed and analyzed to provide fuel droplet position, size, velocity, and evaporation rate as a function of time.

Ultra-High Durability, High-Temperature Spark Delivery Subsystem

The principal objective of this program is to evaluate dielectric breakdown mechanisms in spark plugs for lean-burn engines. As advanced engine concepts begin to approach stoichiometric combustion, higher voltages and temperatures will be required. Enhanced lifetime durability will also be needed and spark plugs will become smaller to allow for other cylinder head modifications, e.g., sensors.

Approach:

The effect of microstructure on dielectric breakdown in alumina ceramic insulating materials is being studied along with the effects of pore size and total porosity. Important objectives include the development of improved alumina insulating materials and glassy sealants.